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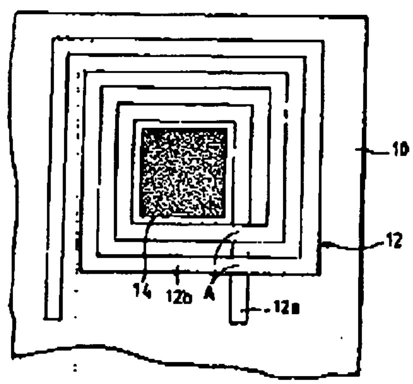
(54) Inductance element.

(57) An inductance element, for use in a microwave integrated circuit for processing high-frequency signals ranging from hundreds of MHz to tens of GHz. A conductor wiring in the form of a thin film is formed by sputtering or the like on a semi-insulating compound semiconductor substrate of GaAs for instance. This conductor wiring is about 2 - 20 um wide. The intersection between a lead wire from the inner end of the conductor wiring and a spiral coil are insulated by means of an air bridge and the like to form a spiral inductor. In the spiral inductor, a core portion made of high permeability magnetic material is provided in the central portion of the spiral and the core portion may be divided into a grid of many small square insulated members. The core portion is directly formed on the substrate by, for instance, sputtering high permeability magnetic material such as nickel. With such an inductance element, the same inductance can be obtained as before with a miniaturized element.

FIG. 1

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## BACKGROUND OF THE INVENTION

### 1. FIELD OF THE INVENTION

The present invention relates to an inductance element, and more particularly to an inductance element for use in a microwave integrated circuit for processing high-frequency signals ranging from hundreds of MHz to tens of GHz.

### 2. DESCRIPTION OF THE RELATED ART

Due to the recent rapid development of information networks, a demand for satellite communication systems is remarkably increasing and a higher range of frequencies within frequency-band designations tends to become selected. Schottky barrier field effect transistors (MESFETs) using GaAs compound semiconductors, for instance, have been put into practical use as high-frequency field effect transistors. Moreover, the integration of the initial-stage amplifier unit of a down converter for converting high frequencies to low frequencies (e.g., the application of MMIC: Monolithic Microwave Integrated Circuit) is progressing for the purpose of not only minimizing the system and reducing manufacturing cost but also improving performance of the system.

The reason for the application of MMIC to such a communication system that has employed a number of discrete elements is attributed to the fact that circuitry integration makes it possible to decrease the number of parts, thus reducing packaging cost. Consequently, system reliability is improved as the number of connections is decreased and the resulting mass production effect facilitates cost reduction in comparison with a case where a number of discrete elements are used for the same purpose.

With such an MMIC, however, it is impossible to fit a coil formed by axially winding a lead wire onto MMIC as an inductance element in the circuit built of a number of discrete elements because the circuit required has to be arranged in one plane.

Consequently, a distributed constant line element such as a micro strip line is employed for MMIC to be used in frequency bands at over about 10 GHz in order to obtain a desired inductance level by setting the shape, width and the like of the relevant strip line properly. In this case, however, the area occupied by the element tends to increase and this trend becomes conspicuous in MMIC for use in low frequency bands. In MMIC, moreover, the yield rate lowers as the chip size increases and this is attended by effects detrimental to cost reduction per chip because the relative number of chips obtainable from one sheet of semiconductor substrate decreases.

In order to solve the foregoing problems accompanying the related art system, there has been proposed a so- called spiral inductor in which a conductor line having width of about 2 - 20 [μm] is formed on a substrate in a spiral manner.

However, due to such an arrangement that a conductor line having width of about 2 - 10 [μm] is arranged spirally, the shape of the spiral inductor is substantially square as a whole. Although it is advantageous in that the area occupied in this case is made smaller than that of an ordinary distributed constant element in view of one element unit, it becomes disadvantageous in that the degree of freedom in designing a layout of the circuit on the substrate is lowered because of the square shape. When various kinds of wiring are actually carried out, there develops a dead space resulting in an occurrence of a problem of increasing the chip size on the whole, which ultimately affects its yield rate and cost.

In case of the distributed constant element in particular, the chip size, far from decreasing, may increase with the use of the spiral inductor, depending on the inductance value and the circuit arrangement, since the degree of freedom in designing the layout is high.

## SUMMARY OF THE INVENTION

In view of the above, it is an object of the present invention to provide an inductance element so designed as to occupy a smaller area.

In order to accomplish the object, an inductance element is formed by arranging spiral conductor wiring in one plane on a semi-insulating compound semiconductor substrate, and a core portion made of high permeability magnetic material is provided in the central portion of the spiral formed by the conductor wiring.

Further, the core portion is formed with a plurality of small members divided and insulated from each other.

The provision of the core portion made of high permeability magnetic material in the central portion of the spiral conductor wiring results in increasing the permeability of the element on the whole, whereby the same L can be obtained as before with a smaller number of turns.

Moreover, a plurality of small members separated and insulated from each other are combined to form the core portion, so that eddy current is prevented from flowing through the core portion. Consequently, the upper limit of an operating frequency for use is elevated.

## BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incor-

porated in and constitute a part of the specification, illustrated presently preferred embodiments of the invention and, together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention. In the accompanying drawings:

Fig. 1 is a plan view of a first embodiment of an inductance element according to the present invention;

Fig. 2 is also a plan view of a second embodiment of an inductance element according to the present invention; and

Fig. 3 is a schematic diagram illustrating a partial cross-section of a core portion of a third embodiment of an inductance element of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the accompanying drawings, a preferred embodiment of the present invention relating to an inductance element will be described.

Fig. 1 is a plan view of a first embodiment of an inductance element according to the present invention. As shown in Fig. 1, conductor wiring 12 in the form of a thin film of gold and the like is formed by vapor deposition or sputtering on a semi-insulating compound semiconductor substrate 10 such as GaAs substrate. In this embodiment, the conductor wiring 12 about 2 - 20 μm in width is spirally arranged and substantially square. However, that shape is not limited to this example but may be substantially circular and optional. Intersections A between a lead wire 12a from the inner end and a spiral coil 12b are insulated by means of an air bridge.

According to the present invention, a core portion 14 which is planar and substantially square as a whole is provided to the central space of a coil portion 12b where no conductor wiring 12 exists. In this case, high permeability magnetic material such as nickel is used to form the core portion 14 directly on the substrate 10 by way of vapor deposition or sputtering.

Further, according to the invention, the core portion 14 may be divided into a grid of many small square members 14a with one side about 1 μm long as shown in Fig. 2. Those small members 14a as a whole are used to form the core portion 14. Although a member-to-member space has to be insulated, it is only necessary to provide a portion where no nickel layer is formed on the substrate as shown in Fig. 2 when the core portion 14 is arranged in one plane.

Furthermore, sputtering equipment and nickel as material for use during the process of manufacturing ordinary MMIC can directly be used in this embodiment since the core portion 14 is to be formed by sputtering nickel. Therefore, there may arise no problem of cost increase and the like because the manufacturing of such a core portion can be dealt with only by increasing the man-hour without the necessity of any new special additional process step.

Although it is preferred to use a mask having a pattern corresponding to the grid of many small members 14a when they are actually formed at a time, the core portion 14 may be formed through two steps of forming a large square core portion once on the substrate and removing spaces in predetermined positions. In other words, the process of manufacture is optional.

Although the shape of the core portion 14 has been set square in conformity with the shape of the coil 12a spirally wound, the core portion may be circular correspondingly when a circular spiral coil is employed or may be shaped optionally in any form irrelevant to the spiral form. This is also the case with the shape of each small member.

Fig. 3 is an enlarged perspective view of a core portion cut in its height direction as a third embodiment of the present invention. As shown in Fig. 3, a core portion 16 is formed by stacking a plurality of layers (four layers in this example) of the core portions 14, each of which includes a plurality of small members 14a of the first embodiment. More specifically, the core portion 16 in this embodiment is formed of first - fourth core members 18, 20, 22, 24 constituting the respective layers and a dielectric thin film 26 about 0.1 - 0.3 μm thick which is held among the core members 18, 20, 22, 24, whereby the adjoining core members are insulated from each other. Moreover, the dielectric thin film 26 also functions as an insulating material among the small members 18a, 20a, 22a, 24a of the respective core members 18, 20, 22, 24.

The permeability of the inductance element can be increased on the whole as the core portion is formed in the central space of the spiral conductor wiring thereof according to the present invention and therefore a high inductance value is obtainable with a relatively small number of turns.

Consequently, the attempt to reduce the size of the element can be implemented and since the degree of freedom of layout at the time the circuit is actually assembled increases, not only the area occupied by the element but also that of the whole chip as a final product becomes reducible. This results in reducing the cost per chip.

Moreover, the number of intersections between the lead wire from the inner end of the conductor wiring and the spiral portion decreases as the number of turns decreases. Further, the number of insulating operations at these intersections de-

creases, so that the process of manufacture is simplified with the secondary effect of reducing cost.

In addition, the eddy current is restrained from flowing through the core portion even at high frequencies since it is formed of the plurality of divided small members. As a result, the upper limit of an operating frequency for use is elevated.

## Claims

1. An inductance element formed by arranging spiral conductor wiring in one plane on a semi-insulating compound semiconductor substrate, comprising a core portion made of high permeability magnetic material which is provided in the central portion of the spiral formed by said conductor wiring.

2. The inductance element as defined in claim 1 wherein said core portion comprises a plurality of small members divided and insulated from each other.

3. The inductance element as defined in claim 1 wherein said semi-insulating compound semiconductor substrate is GaAs substrate.

4. The inductance element as defined in claim 2 wherein said semi-insulating compound semiconductor substrate is GaAs substrate.

5. The inductance element as defined in claim 1 wherein said high permeability magnetic material is nickel.

6. The inductance element as defined in claim 2 wherein said high permeability magnetic material is nickel.

FIG. 1

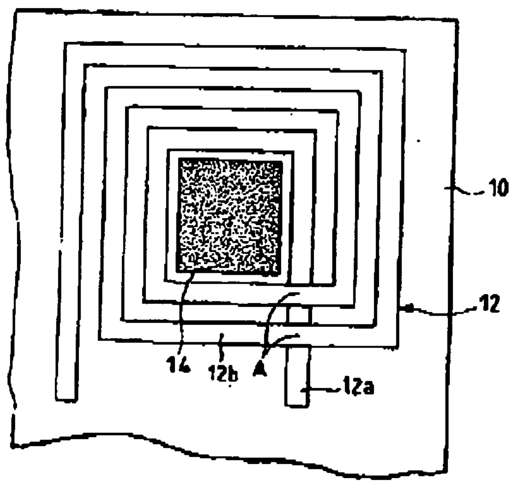



FIG. 2

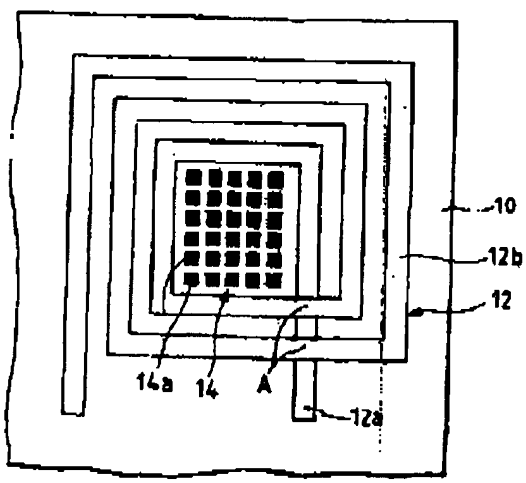
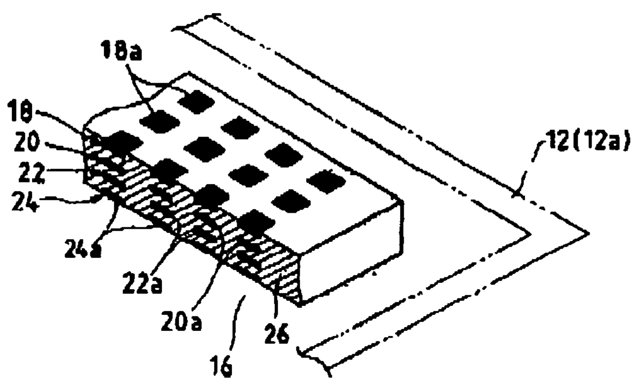


FIG. 3



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# EUROPEAN SEARCH REPORT

Application Number

EP 92111147.2

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|---|---|---|---|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.5) |
| A | US - A - 3 798 059 (ASTLE) * Abstract; fig. 1-6; claims 1-13 * -- | 1 | H 01 P 5/00 |
| A | US - A - 4 494 100 (STENGEL) * Abstract; fig. 1-7 * -- | 1 | |
| A | US - A - 4 689 594 (KAWABATA) * Abstract; fig. 1 * -- | 1 | |
| A | EP - A - 0 310 396 (KABUSHIKI) * Abstract; fig. 1,7,12; claims 1-13 * ---- | 1 | |

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

H 01 P 5/00
H 01 P 17/00

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| VIENNA | 22-10-1992 | VAKIL |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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